

THURSDAY, JANUARY 31, 1901.

THE SCIENCE OF SPECTRUM ANALYSIS.

Handbuch der Spectroscopie. By H. Kayser. Professor of Physics at the University of Bonn. Vol. i. Pp. xxiv + 782. 251 figures. (Leipzig: Hirzel, 1900.)

THERE are comparatively few men of science who can accurately handle a spectroscopic and interpret its indications with assurance. The number of chemists, for instance, who could look at the spectrum of a Geissler tube, and pick out at once the lines of hydrogen, oxygen, nitrogen or carbon, is probably very small. No one denies the importance of the spectroscopic method, but its practice requires so long an apprenticeship and so severe a training, while the experimental facts are so numerous and the pit-falls so plentiful, that the physicists and chemists are inclined to shirk the whole subject and to leave it to the few who happen to have been brought up in a spectroscopic atmosphere.

Part of the cause of this apparent neglect is due to the want of a proper guide to lead the willing but bewildered student through the intricacies of a most diffuse and uninviting literature. We possess only a few short textbooks which are quite insufficient for any serious requirements, and various catalogues of papers relating to spectrum analysis which have proved absolutely useless. Prof. H. Kayser, well known as an authority on the subject, has undertaken what must prove to be the work of a lifetime. The first volume of his "Treatise of Spectroscopy" is now completed and will be welcomed by all who desire to know, as well as by those who already know, something of this branch of science.

This volume covers 750 pages and deals, after an historical introduction, with the instrumental methods of producing and examining spectra. There can be only one opinion on the admirable manner in which Prof. Kayser has accomplished his task. He has succeeded in giving a clear and complete account of his subject, and at the same time avoided overburdening his book with details, which the reader can always find in the original papers, to which complete references are given.

The first 120 pages are devoted to the history of the subject, which is dealt with in a fair and impartial spirit. The early papers, in which ideas, *now* so obvious to us, are present in a vague and intangible form, are fully dealt with, but we naturally turn to the exciting time when Kirchhoff and Bunsen finally disposed of all vagueness and created the science of spectrum analysis. Questions of priority never remain long in an acute stage, and no one would now detract one tittle from Kirchhoff and Bunsen's merit because others may have had some correct ideas before them. Balfour Stewart came very near the truth, but it is very doubtful whether, even if his treatment of the relation between absorption and emission had been as rigid and conclusive as that of Kirchhoff, he would have carried the scientific world with him in the way the Heidelberg philosophers did. In fact, only a small fraction of the chemists and physicists who hailed the new discovery with delight could possibly have appreciated Kirchhoff's mathematical deductions. Even

making full allowance for the fact that most men are more easily convinced by an argument which is entirely beyond their comprehension than by one which they partially understand, I cannot believe that the turning point in the history of spectrum analysis lay in Kirchhoff's theoretical proof of the cause of the reversal of the bright lines. The most interesting portion of the history of science lies, to my mind, not so much in studying the evolution of clear ideas from vague forebodings of truth (though that, no doubt, is of great importance), as in tracing the particular theoretical argument or experimental fact which carried conviction. In this respect, I should give the foremost place in the history of spectrum analysis to Kirchhoff's experiment, in which he actually obtained the reversal of the sodium and lithium lines, and I should give almost equal value to the clear insight and experimental skill which allowed Kirchhoff and Bunsen to assign the D lines with certainty to sodium alone. For the ubiquitousness of these lines was one of the great stumbling blocks which had prevented every real advance, by suggesting that different elements might emit the same vibrations. Even those who had recognised that the yellow lines owed their origin to the presence of a sodium salt had failed to realise that the salt itself was decomposed, and that the lines were due to the metallic element.

There is an interesting incident connected with this point which may be mentioned here, though private conversations, unconfirmed by documentary evidence, have no real value in questions of history. The late Prof. Balfour Stewart assigned his own failure to carry his researches to their logical conclusion to his ignorance of the fact that salt was decomposed in the flame. He made an experiment to see whether rock-salt exercised a selective absorption for light emitted by a sodium flame, and failing to discover such an absorption put the matter aside. But I have been carried away by old recollections, and must pass on from Prof. Kayser's first chapter, which carries the history of the subject to Zeeman's discovery, and the Baltimore experiments on the influence of pressure.

The second chapter deals with the methods of producing luminous vapours. Flames, the voltaic arc, electric sparks in various forms and conditions, and vacuum tubes are discussed in succession; and even those conversant with the subject will find a large amount of valuable information, especially as the author includes in the discussion such questions as the temperatures of different sources, and touches on the theory of the electric discharge.

The third chapter, dealing with prisms, has been written by Dr. H. Koenig of Bonn. The passage of rays through prisms is traced, and full justice is done to Lord Rayleigh's investigations, though two propositions in §§ 309 and 310, assigned to Wadsworth, are really contained in Rayleigh's first paper. I think that the investigations of this chapter might have been made clearer and shorter by a more frequent application of Fermat's principle. Special attention may be drawn to the reduction of prismatic measurements to wave-lengths by means of the interpolation formulæ, which have been given by Cornu and Hartmann (§§ 327 and 328). Insufficient attention, to which I must plead guilty myself, has been given

in this country to these equations, which are much more convenient than Cauchy's formula, and which much facilitate the reduction of measurements made with prism spectroscopes. The chapter concludes with a complete description of the various devices for compound and direct vision prisms. The combination of prisms to obtain great dispersion and resolving power has lost a great portion of its interest since the more general introduction of diffraction-gratings for spectroscopic purposes. We therefore turn with special interest to the fourth chapter, which deals with diffraction-gratings.

After a short history of the methods of ruling gratings, a discussion of plane gratings is given, which chiefly follows Rowland's and Cornu's investigations. About thirty pages are devoted to concave gratings. A very clear and elegant theory of these gratings, due to Prof. Runge, is, for the first time, published in full, and deserves to be widely read. It includes the very important practical question of the easiest method of adjusting the relative position of the slit, grating and camera, so that when the carriages roll along the beams, the spectrum should remain in focus and be displaced only in a direction parallel to the plane containing the two rectangular rails.

A disadvantage of concave gratings, which has been pointed out by Rowland in his first discussion, is its astigmatism, a point on the slit being drawn out into a line. It seems to me a curious fact that no one should have attempted to correct this astigmatism by means of cylindrical lenses. I was only waiting until the large concave grating of the Owens College was available, to try some experiments in this direction. Prof. Fitzgerald tells me that he has had the same idea, and has already determined by experiment the proper position of the two focal lines of the correcting lens. In looking over the pages of Prof. Kayser's book, I find that I had overlooked a paper by Mr. J. L. Serks, in the *Journal of Astronomy and Astrophysics*, in which the question is, in fact, solved theoretically. It is curious, however, that the author does not seem to have realised this application of his investigation, which he only applied to proving the possibility of finding a position for a comparison prism such that the horizontal edges of the prism should appear sharp on the spectrum plate. If the light coming from a luminous point is passed through a combination of a cylindrical and convex lens, placed so as to give a horizontal focal line in the position given by Serks, and a vertical focal line coincident with the slit, the astigmatism of the concave grating will be corrected.

The fifth chapter discusses the construction of spectroscopes, a good deal of space being devoted to the various devices for securing minimum deviation. The author seems to me to attach a somewhat exaggerated importance to the minimum deviation as regards its necessity to give definition. If the collimator is properly adjusted, and the faces of the prisms are plane, the spectra should be equally perfect whether the prisms are in the position of minimum deviation or not. When many prisms are used it becomes, of course, necessary that each prism should wholly take in the beam of light which has passed through the previous prism, and, in that case, the position of minimum deviation is most con-

venient. For the usual prism, cut so that its base is equally inclined to the faces, the position of minimum deviation is also that of maximum resolving power; but the prism may be turned considerably out of the symmetrical position without sensibly affecting its power of resolution.

The theory of the spectroscope, including the question of resolving power and purity, is fully discussed; but I venture to think that the treatment of the brightness of spectroscopic images might be made much simpler and clearer, and in some cases more correct, by starting from the following two very simple principles.

It is a well-known proposition, in the formation of images by lenses, that the brightness of the image, as deduced from the laws of geometrical optics, simply depends on the emitting power of the source and on the solid angle of the converging beam forming the final image. When the observations are taken by the eye, and the whole pupil is filled with light, the last solid angle is fixed; hence the brightness cannot be altered by any optical arrangement. The same proposition also holds when the light is refracted through prisms, provided the light is homogeneous. The second proposition, to which I have alluded, states that if the object is linear, the width of the central image, due to the finiteness of the wave-length of light, also depends only on the solid angle of the conical beam forming the last image.

These two propositions enable us to draw all the necessary conclusions without restrictions, such as that made by Kayser as to the position of minimum deviation of the prisms; and the results of § 508, derived from a paper by Wadsworth, will be found to need correction in some important particulars. The latter portions of this chapter deal with Michelson's researches, the applications of fluorescence, phosphorescence, and finally with photographic and bolometric methods.

The last chapter is devoted to spectroscopic measurements.

The value of the book is increased by the fact that the author has not been satisfied with a statement of results, but in many cases has added his own criticisms. I entirely agree with the statement made in the preface, that a mere compilation without critical discussion is of very little value. In the present volume there has not been so much opportunity of touching on tender spots as will arise in subsequent divisions of the subject; but Prof. Kayser's evident fairness and knowledge of his subject render it certain that no one need be afraid of placing himself under the judgment of so competent an authority. While congratulating Prof. Kayser on the successful accomplishment of the first portion of his task, we conclude with the hope that we may soon be able to welcome a second volume. ARTHUR SCHUSTER.

LIFE AND WORK OF C. GERHARDT.

Charles Gerhardt: sa Vie, son Oeuvre, sa Correspondance: 1816-1856. Document d'Histoire de la Chimie. Par M. Édouard Grimaux et M. Charles Gerhardt. (Paris: Masson et Cie.)

A BIOGRAPHY which involves the history of the turning-point of a science is always interesting; and this one in particular, which tells the tale of the